

(NASA-CR-199531)

~~(NIPS-95-05513)~~ THE
STREAMING-TRAPPED ION INTERFACE IN
THE EQUATORIAL INNER MAGNETOSPHERE
(NASA. Marshall Space Flight
Center) 45 p

N96-13103

Unclass

G3/46 0072792

For Dr. Pollock

THE STREAMING-TRAPPED ION INTERFACE IN THE EQUATORIAL INNER MAGNETOSPHERE

NAG 8-134

1N-46-CR

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ABSTRACT

Spacecraft measurements of core ions on L=4-7 field-lines typically show trapped ion distributions near the magnetic equator, and frequently indicate field-aligned ion streams at higher latitudes. (e.g., Olsen et al. [1987]). The nature of the transition between them may indicate both the microphysics of hot-cold plasma interactions and overall consequences for core plasma evolution. We have undertaken a statistical analysis and characterization of this interface and its relation to the equatorial region of the inner magnetosphere. In this analysis, we have characterized such features as the equatorial ion flux anisotropy, the penetration of field-aligned ionospheric streams into the equatorial region, the scale of the transition into trapped ion populations, and the transition latitude. We found that most transition latitudes occur within 13° of the equator. The typical values of equatorial ion anisotropies are consistent with bi-Maxwellian temperature ratios of $T_\perp/T_\parallel$ in the range of 3-5. The latitudinal scales for the edges of the trapped ion populations display a rather strong peak in the $2 - 3^\circ$ range. We also found that there is a trend for the penetration ratio, the anisotropy half width, and the transition scale length to decrease with a higher equatorial ion anisotropy. We may interpret these features in terms of Liouville mapping of equatorially trapped ions and the reflection of the incoming ionospheric ion streams from the equatorial potential peaks associated with such trapped ions.

near $L=4$
(4-6?),
plasma pause!

1. INTRODUCTION:

with pitch angle distributions
peaked near 90° .

Spacecraft measurements at times show a latitudinal transition of core ion (0-50 eV) fluxes in which trapped ions are seen centered about the magnetic equator and counter-streaming ions are seen at off-equatorial latitudes (e.g., Olsen et al. [1987]). This indicates ~~the process of trapping~~ the field-aligned flowing ions in the equatorial regions, which is an ~~that trapping of~~ important aspect of plasmasphere refilling. The nature of this interface is quite interesting from the standpoint of both the microphysics of hot-cold plasma interactions and overall consequences for core plasma evolution.

There are a variety of core plasma observations near the equator in the vicinity of the plasmapause. These observations often reveal plasma pitch angle distribution with peaks at 90° (pancake or trapped distributions) and characteristic energies of several electron volts (e.g. Horwitz and Chappell, 1979; Comfort and Horwitz, 1981; Horwitz et al, 1981b; Olsen, 1981; Olsen et al., 1987, Sagawa et al. 1987). Since these ions originate in the ionosphere, it is clear that they have been subjected to perpendicular heating which are presumably responsible for the waves associated with coexisting ring current populations.

Sagawa et al. [1987] find the occurrence frequencies for such trapped distributions observed within 5° of the magnetic equator to be in the $L=3.5-5$ range. They also find broadened field-aligned distributions and conics ~~within~~ ^{at} middle latitudes in the outer plasmasphere, which may indicate wave-particle interactions at lower altitudes along these field lines.

Singh and Hwang [1987] have examined the equatorial trapped ions in the refilling processes and suggested that the equatorial heating is likely to set up ^a downward electric field due to the difference ⁱⁿ of pitch angle anisotropies of the trapped ions and electrons at the equator. The electric fields and the associated potentials ^{near} the equator were estimated to be large enough to reflect the field-aligned flows reaching the equator (Singh and Torr, 1988). Lin et al. [1994] have used Generalized SemiKinetic Modeling (GSK) to simulate

suggest you use the words
"ambipolar electric field."

peak in the $L=3.5-5$ range!

development of the potential structure and the reflection of the incoming ionospheric flows, and demonstrated effects of hemispheric decoupling and asymmetric refilling owing to such equatorial potential peaks.

In recent years, several new characteristics of thermal plasma distributions have been observed ^{using} ~~by~~ DE-1/RIMS (Dynamics Explorer-1/ Retarding Ion Mass Spectrometer) [e.g. Chappell et al, 1981]. The RIMS instrument ^{was} ~~is~~ designed to measure the energy and angular distributions of low-energy ions for various ion species. In particular, analysis of RIMS ion data provides estimates of wide ranges of thermal ion bulk parameters, including the ion density ($0.1-10^6$ ions/cm³), temperature (0-45 eV), and bulk flow (> 0.5 km/sec) in the inner plasmasphere and ionosphere and the ~~specific~~ ion pitch angle and energy spectral characteristics in the outer plasmasphere and plasma trough for a mass range 1-32 amu. The RIMS instrument consists of a central electronics assembly and three separate sensor heads, one mounted viewing perpendicular to the ^{spacecraft} spin axis and two each mounted with field of view parallel and anti-parallel to the ~~spacecraft~~ spin axis. ^(radial head) ^(2-heads)

An unique opportunity offered by DE 1 core ion observations was that during certain periods the satellite orbit essentially skimmed a large latitudinal segment of approximately constant L shell of ~ 4.6 (in the vicinity of plasmapause) about the equator. This allowed excellent measurements of the latitudinal profile of the particles and fields in this region. Olsen et al. [1987] utilized such orbits to examine the characteristics of the low energy ions and waves in this region. They observe ^a strongly confined light ions about the equator and equatorially confined broadband, low frequency electrostatic waves. Olsen et al. [1987] also show ^{data} in which there is either a gradual fade in the intensity of field-aligned flows or what appears to be field-aligned ion beams reflecting from a thin potential structure.

The low penetration ratios of field-aligned streams into the equatorial regions in some cases imply ^{thin} electrostatic potential layers which are indicative of important laminar [?] hot-cold plasma interactions. Such layers also should lead to hemispheric decoupling and

3
why is a thin layer, rather than a distributed gradient implied?

hence have major consequences for the plasma evolution along these refilling flux tubes. As noted above, Lin et al. [1994] have simulated core plasma evolution with equatorial ion and electron heating. They found that, around the equator, electrostatic potential barriers developed and resulted in reflection of incoming ionospheric flows and hence strongly influenced the bulk parameter profile evolution. Olsen et al. [1987] have obtained the electric field of about $0.1 \mu\text{V}/\text{m}$ by referring to the model of Liouville mapping and bi-Maxwellian distribution for equatorial trapped ions (Olsen [1981]). Such potentials have been proposed as an explanation for the changes in field-aligned ion behavior in the DE 1 data set.

In this report, we present the results of a statistical study of the properties of the transition between the trapped and field-aligned ion fluxes in the equatorial region, using DE 1/RIMS data of mid-1982 and late 1983, ^{when the} ~~whose~~ orbit was particularly suited to latitudinal profiles with nearly constant L , with apogee near the equator. In this analysis, we have characterized such features as the equatorial ion flux anisotropy, the penetration of field-aligned ionospheric streams into the equatorial region, the scale of the transition into trapped ion populations, and the transition latitude. Statistical properties and correlations of these parameters will be described. These features will be interpreted in terms of Liouville mapping of equatorially trapped ions and the reflection of the incoming ionospheric ion streams from the equatorial potential peaks.

In section 2, we will describe data analysis methods used including criteria for selected DE-1 measurements and parameter definitions. In this section, the method of Liouville mapping will also be briefly described. Section 3 describes the results including statistical occurrence trends and corrections between defined parameters. A discussion and conclusion are given in section 4.

2. METHOD

2.1 Criteria for selected DE-1 measurements

A statistical study of the properties of the latitudinal transition between the trapped and field-aligned ion fluxes in the equatorial region has been investigated by utilizing RIMS core ion data from DE-1 orbits which nearly "skim" along the L=4.6 shell. The criteria for selection of appropriate passes are first that they involve a transition from trapped to counter-streaming H^+ ions and that the variation of L-shell near this transition is small.

Figures 1 and 2 show two typical spectrograms for DE-1 passes through the equatorial region when the spacecraft apogee was near the equator. These two panels are spin-time spectrograms of ion count rates data taken at 0 V retarding potential. The center line is the ram direction which is nearly zero degrees pitch angle. The minimum pitch angle (near 0°) is indicated by white line running along the center of the spectrogram. The white line near the bottom of the panel indicates the spin phase for maximum pitch angle (near 180°). The ~~fluxes~~ ^{particles/min} count rates are color coded with dark blue representing low count rates and red representing high count rate. The color bar on the left hand side shows this scale. Note that the two spectrograms have been scaled differently to emphasize the desired features. The equatorially trapped proton distribution appears as the red region between the two white lines in both figures, indicating a flux peak ^{near} ~~at~~ 90° pitch angle. Prior to the spacecraft encounter with these trapped ions, the proton distribution is primarily field-aligned (fluxes peaked along the white lines) in both cases. The principal difference between the two cases is that Figure 1 shows an abrupt transition from field-aligned to trapped protons and very low penetration of the field-aligned protons into the trapped ion region while Fig 2 shows a more diffuse transition and higher penetration of field-aligned protons into the trapped ion region. It is evident that analysis of such transitions in this region will aid significantly in understanding the nature of the large-scale core plasma evolution on these flux tubes.

does this
rule out
cases with $p > 1$?

Regarding our criterion for the acceptability of DE-1 passes for this study, the unique capability for sampling the distributions of core ions along the field line in the vicinity of the magnetic equator is illustrated for two example orbits in Figures 3 and 4. Figure 3 shows the DE-1 orbit for the period 09:00-12:00 of May 6, 1982 (82-126) ~~May 1982 - Day 126~~ superposed on model dipole field lines projected to a geocentric distance-magnetic latitude plane. The orbits, of course, do not stay precisely on an L=4.6 shell, and this aspect does introduce the possibility of L-shell variations, as opposed to the desired latitudinal variations alone, affecting the observed plasma distributions. Therefore, we calculate the L-shell variation between $\lambda = +10^\circ - 0^\circ$ or $\lambda = -10^\circ - 0^\circ$ (depending on which hemisphere the transition point is located), which generally brackets both the equator and the observed field-aligned/trapped transition locations.

$$LL = |L_{\lambda=\pm 10^\circ} - L_{\lambda=0^\circ}| \quad (1)$$

For the cases in Figures 3 and 4, the LL values for 82-126 and 83-295 were 0.13 and 0.36, respectively. ~~All~~ ^{NO} cases with LL values greater than 0.36 were ~~not~~ considered.

The observation periods for this study were May to September, 1982 and September to December, 1983. Over these two periods, 43 passes satisfied our LL criterion for nearly-skimming orbits.

2.2 *Extracted parameters for survey*

In this survey, we have obtained five parameters for each pass for characterization of this region. These parameters are the equatorial ion anisotropy, anisotropy half-width, the transition latitude, the transition latitudinal scale length, and the penetration ratio for incoming field-aligned streams entering the trapped ion region. Figure 5 shows plots of count rates at different spin/pitch angles and their ratios together with parameter definitions for the 82-126 data. The data we have ^{used} ~~used~~ is actually organized in terms of spin

angle, while we need the count rates in terms of pitch angle, and the relationship between spin angle and pitch angle changes somewhat during the equatorial pass. Therefore we have used the following approximate approach.

For the maximum anisotropy and latitudinal width parameters, we used and plotted (top panel of Figure 5) the ratio of the count rates at spin angles corresponding to pitch angles of 90° and 45° for the spin-pitch angle relationship at the magnetic equator indicated from the orbital data. For example, if the white line which represents the minimum pitch angle is located at spin angle 15° while it passes the magnetic equator, the trapped ion population is taken in the range of spin angle $\theta = 105 \pm 20^\circ$, where 105° is the 90° pitch angle for trapped ions in addition to spin-pitch angle difference 15° .

To estimate the field-aligned count rate variations along the orbit, we have used and plotted (middle panel of Figure 5) the count rates which correspond to the minimum pitch angle at the transition location. This transition location is initially determined roughly from the microfiche spectrograms as the apparent edge of the trapped ion distribution region.

To obtain the actual trapped ion transition location, we have used and plotted (bottom panel of Figure 5) the ratio of the count rates at spin angles corresponding to pitch angles of 90° and 45° for the spin-pitch angle relationship at the spectrogram determined transition location.

For cases where the orbit follows the L-shell closely, as in Figure 5, the spin-pitch angle relationship is nearly constant, and thus the difference in the ratio in the top and bottom panel is slight; but in other cases it can be significant and it is necessary to do these two different calculations (both the transition point and the equator). For the parameters determined from the data of the type in the top and middle plots in Figure 5, we have performed a three-point weighted average smoothing (solid lines) of the ¹ minute samples (dashed lines) before computing the parameters as below.

These parameters are defined as follows:

Equatorial Ion Anisotropy

According to Lin et al. [1994] and earlier modeling efforts, it is known that the equatorial ion temperature anisotropy will affect refilling and interhemispheric plasma exchange. Hence, the equatorial anisotropy will be a determining factor in this study. Here we define the maximum equatorial anisotropy A_{max} from the variation of count rates as:

$$A_{max} = \text{MAX}_{\text{orbit}} \left(\frac{CR(90^\circ)}{CR(45^\circ)} \right)$$
$$A_{max} = \frac{CR(\alpha = 90^\circ)}{CR(\alpha = 45^\circ)} \quad (2)$$

where CR is the ion count rate and the ratio is the maximum anisotropy along the orbit. The location of A_{max} is generally near or at the nominal equator. Note that $CR(\alpha = 45^\circ)$ instead of $CR(\alpha = 0^\circ)$ is chosen to be the denominator here. This is because, for example, when both counterstreaming and trapped populations have similar count rates, the value of $\frac{CR(\alpha=90^\circ)}{CR(\alpha=0^\circ)}$ will be close to 1, while the distribution may not be isotropic.

We note here that A_{max} is not always located at the nominal equator obtained from DE orbit-altitude data. In this study we have tried another method to determine the location of the equator. Considering a dipole field, we mapped the measured B magnitude to a consistent L-shell value at the corresponding latitude. In other words, we corrected the measured B field to compensate the variation in spacecraft radial distance along its orbit to better determine the time of equatorial crossing based on corrected B field strength minimum. We found that neither the location of B_{min} nor the location of the magnetic equator obtained from the simple model used in the DE orbit data is always consistent with the location of A_{max} . However, we normally regard A_{max} to be the physically most meaningful parameter (especially in relation to the field-aligned penetration ratio), and so we have chosen its location to be the effective magnetic equator in this study.

Anisotropy half width (W)

To estimate the rapidity of the temperature anisotropy decline from the maximum anisotropy location, we define the Anisotropy Half Width (W) as the latitudinal distance between the locations of the maximum anisotropy value and the half maximum anisotropy value.

Transition latitude for trapped ions (λ_{tr})

The Transition Latitude (λ_{tr}) is defined as the latitude of the first data point toward the equator of three consecutive data points which have anisotropy greater than 1.2. This location is intended to indicate the entry into the edge of the trapped ion region. The value $A \geq 1.2$ is chosen by making a comparison between the spectrogram from microfiche and the ion anisotropy profile. The requirement for three consecutive points with $A \geq 1.2$ is to discard potentially noisy or intermittent excursions above the 1.2 threshold.

The transition latitudes obtained for the passes of 82-126 and 84-068 (in Figures 1 and 2) were at -6.07° and 12.5° , respectively.

Transition Latitudinal Scale Length ($\lambda_s(trapped)$)

To indicate the sharpness of the trapped ion transition, we define $\lambda_s(trapped)$, the latitudinal scale length associated with the trapped flux decrease at the transition, as

$$\Delta \lambda_s(trapped) = CR_{trans} \times \left[\frac{dCR}{d\lambda} \right]^{-1} \quad (3)$$

How about $A \times \left[\frac{dA}{d\lambda} \right]^{-1}$?

where $\frac{dCR}{d\lambda}$ is evaluated about the transition latitude by taking the slope of CR from $\lambda_{tr} - 1$ to $\lambda_{tr} + 1$ and CR_{trans} is defined by the average count rate in the same range.

The latitudinal scale lengths of the above passes on 82-126 and 84-068 are 1.29° and 5.63° , respectively.

Penetration Ratio for Incoming Field-Aligned Ions (P)

A measure of how much equatorial penetration of the field-aligned ions occurs reveals information on the electrostatic potential structure along the field line. We define P , the penetration ratio of counterstreaming ions, as the ratio of the minimum field-aligned flux observed between the transition latitude and the equator to the field-aligned flux observed just outside the transition location. To define P , we decided that the minimum flux observed between the transition latitude and the equator would be a better choice for the numerator than the field-aligned flux precisely at the equator or the A_{max} location. This is in part because the largest potential barriers which will reflect the incoming flux could in principle be at slightly off-equatorial latitudes. Hence, the minimum flux between the transition latitude and the equator could be correlated to this largest potential barrier. The penetration ratios for the passes of 82-126 and 84-068 were 0.28 and 0.78, respectively.

Obtained parameters for the example passes

Surprised this is so large!

Factor is tropic. Enhances at equator or 62°E max hold P. Artificially high for high case!

Table 1 lists the obtained parameters for the two example passes discussed here.

2.3 Assumptions for the relation between A_{max} and the equatorial temperature anisotropy

As mentioned before, the equatorial ion anisotropy A_{max} is a determining factor in this study. Here, we will introduce an approximate method to find the relationship between A_{max} as defined here and $T_{\perp}/T_{\parallel}(eq)$ for a ^{sampled} detected bi-Maxwellian ion distribution. For an arbitrary ion distribution function $f(\vec{v})$, we can calculate the count rate into the detector aperture, ~~can~~ may be estimated as

$$CR(\alpha) = C_0 \left| \int d\phi \int \sin\theta d\theta v^2 dv f(\vec{v}) \vec{v} \cdot \hat{d} \right| \quad (4)$$

Must fill $\Delta\Omega, \Delta A, \Delta E$

and variation of detector response with ion energy and angle of incidence has been neglected.

Table 1: Parameters of two DE-1 example passes

Parameter	82-126	84-068
λ_s	1.29	5.63
P	0.28	0.78
λ_{tr}	-6.07	12.5
A_{max}	10.12	2.99

anti parallel to detector look direction

where θ , ϕ and $\hat{d}$ are the polar angle relative to the magnetic field, the azimuthal angle and the unit vector ~~normal to the detector~~, respectively, and $\vec{v}$ is the ion's velocity vector. The angular integration is over the range subtended by the detector aperture fan. C_0 is a constant determined by ~~the relationship between ion flux and ion count rates~~. The polar angle θ is the angle between the magnetic field direction and the normal vector of the detector.

For RIMS, the ~~angular acceptance~~ ^{sensitive} solid angle decreases with increasing ion energy and mass (Chappell et al. [1981]). ~~As the beam energy and mass number increase, the angular response becomes significantly affected by the angular acceptance of the magnet assembly. This results in a narrowing of the angular acceptance for higher energies and masses.~~ S. Boardsen (private communication, 1993) has suggested the following approximation for the energy dependence of the RIMS ~~acceptance~~ solid angle:

$$S = S_0 \cdot \exp(-E/kT_d)$$

Where E is the energy of the ion and kT_d is the effective energy of the detector (about 60 eV for RIMS).

is an energy scale characteristic of the instrument at the aperture

For present purposes, we will assume the effective ~~detector~~ solid angle is a function of the ion's energy ($S = S(E)$) as indicated above. For qualitative purposes here, we will further assume that the detector solid angle is small enough ~~such~~ that the integration can be approximated as a simple constant multiplication, giving

$$CR(\alpha) = C_0 \cdot S_0 \cdot \int v^3 dv f(v) \exp(-(E - q\Phi_p)/kT_d) \quad (6)$$

where Φ_p is the spacecraft potential, q is the ion charge, and α is the pitch angle.

We will further assume that the ion distribution is a bi-Maxwellian distribution:

$$f(v) = n_0 \frac{(m/2k\pi)^{3/2}}{\sqrt{T_{\parallel}T_{\perp}}} \exp[-(\frac{\cos^2\alpha}{T_{\parallel}} + \frac{\sin^2\alpha}{T_{\perp}})E] \quad (7)$$

After substituting the ion distribution function into equation (6), we can integrate with respect to energy from E_{min} to ∞ and obtain the count rate as:

$$CR(\alpha) = C_1 \exp[E_{min}/T_d] \cdot \int_{E_{min}}^{\infty} [E \cdot \exp(-GE/T_{\perp})] dE \quad (8)$$

$$= -C_1 \cdot T_{\perp}^2 \cdot \exp[E_{min}/T_d] \cdot \exp[-GE_{min}/T_{\perp}] \cdot (\frac{E_{min}}{T_{\perp}} - \frac{1}{G})/G \quad (9)$$

where

$$G = \frac{T_{\perp}}{T_d} + (\frac{T_{\perp}}{T_{\parallel}} - 1) \cdot \cos^2 \alpha + 1 \quad (10)$$

~~E_{min} is the spacecraft charged electric potential energy $q\Phi_p$~~ and C_1 absorbs the constants of the distribution function and the detector. The lower limit of the energy integration E_{min} indicates that only ions with greater energy than $q\Phi$ will be detected.

We did not try to measure the perpendicular temperature for the present analyses, although this is in principle possible during these periods using the Z-heads of RIMS (e.g. Olsen et al. [1994]). However, if we assume that E_{min} ~~is~~ 0 , the spacecraft ~~negatively~~ ^{is}

E_{min} is the minimum energy required for an ion to reach the charged spacecraft, at potential Φ_p ...

^{charged} charged or unbiased then the ratio of the ion count rates at pitch angles of 90° and 45° is related to the ion temperature anisotropy as

$$A = \frac{CR(90)}{CR(45)} = \left[\frac{\frac{T_{\perp}}{T_d} + \frac{1}{2} \left(\frac{T_{\perp}}{T_{\parallel}} + 1 \right)}{\frac{T_{\perp}}{T_d} + 1} \right]^2 \quad (11)$$

For cases where the perpendicular temperature is much less than 60 eV, $\frac{T_{\perp}}{T_d} \ll 1$, the relationship is

$$\frac{CR(90)}{CR(45)} = \frac{\left(\frac{T_{\perp}}{T_{\parallel}} + 1 \right)^2}{4} \quad (12)$$

For cases where the perpendicular temperature is near 60 eV, i. e., $\frac{T_{\perp}}{T_d} \approx 1$, the relationship is

$$\frac{CR(90)}{CR(45)} = \frac{\left(\frac{T_{\perp}}{T_{\parallel}} + 3 \right)^2}{16} \quad (13)$$

2.4 A simple model for the interpretation of equatorial core ion data

We will also discuss in greater detail the correlations among the parameters we defined in previous section (A_{max} , λ_{tr} , λ_s , W , P) and possible physics that these trends indicate. We will do this by the aid of equations obtained by Liouville mapping of the ion distribution function along the field line.

Here we will assume a bi-Maxwellian ion distribution function at the equator, and obtain the distribution function along the the same field line. Let the equatorial distribution be

$$f(V_{\parallel}, V_{\perp})_{eq} = n_o \cdot \frac{(m/2k\pi)^{3/2}}{\sqrt{T_{\parallel eq} T_{\perp eq}}} \cdot \exp\left(-\frac{mV_{\parallel eq}^2}{2kT_{\parallel eq}} - \frac{mV_{\perp eq}^2}{2kT_{\perp eq}}\right) \quad (14)$$

To map this distribution to an off-equatorial location λ , we assume constancy of the ion magnetic moment and energy conservation and rearrange the resulting mapped distribution

function in the form of a bi-Maxwellian outside of a "forbidden region" in velocity space associated with the potential (e.g., Chiu and Schulz [1978]; Whipple [1977]). We can obtain the potential distribution along the field line, if we specify a bi-Maxwellian or isotropic equatorial electron distribution, require quasi-neutrality, and assume that the forbidden region ^{is} smoothly filled in by the ions confined in the region between the equatorial potential and the mirror points (e.g., Olsen et al. [1994]).

Under these conditions, the parallel temperature is constant along the field line, while the variation of the perpendicular temperature is given by $\frac{T_{\perp}}{T_{\parallel}} \frac{T_{\perp eq}}{T_{\perp \lambda}} = \frac{T_{\perp eq}}{T_{\parallel}} [1 - R_B] R_{T_{eq}} + R_B$

$$T_{\perp \lambda} = \frac{T_{\perp eq}}{\left\{ \left[1 - \frac{B_{eq}}{B_{\lambda}} \right] \frac{T_{\perp}}{T_{\parallel}} (eq) + \frac{B_{eq}}{B_{\lambda}} \right\}} = \frac{T_{\perp eq}}{[1 - R_B] R_{T_{eq}} + R_B} \quad (15)$$

where $R_{T_{eq}} = T_{\perp eq} / T_{\parallel eq}$, $R_B = B_{eq} / B_{\lambda}$.

The variation of the ion density along the field line can also be obtained this mapping (e.g. Olsen et al. [1993]).

a. Estimation of $\Delta\Phi$ from A_{max}

If we further assume that the electron temperature is isotropic and satisfies Boltzmann relation for the electrons, we can obtain the potential as it varies from the magnetic equator as:

$$\Delta\Phi = \frac{kT_{e\parallel} T_{\parallel i}}{e[T_{e\parallel} + T_{\parallel i}]} \ln \left[\frac{1}{R_B + (1 - R_B) R_{T_{eq}}} \right] \quad (16)$$

where $R_B = B_{eq} / B_{\lambda}$ and $R_{T_{eq}} = T_{\perp i} / T_{\parallel i}$

Assuming the potential distribution is dictated largely by differential anisotropy between the ions and electrons, we can use equation (16) to relate the maximum anisotropy (A_{max}) and potential drop at a given location ($\Delta\Phi$). Therefore, at a given location and

electron temperature, we can find the relationship between $\Delta\Phi$ and R_{Teq} and hence $\Delta\Phi$ and A_{max} .

b. Relationship between a reflecting potential drop ($\Delta\Phi$) and P

We can estimate the potential drop associated with the reflection of ion streams for a given penetration ratio as follows. Let us assume for simplicity that the ion streaming distribution entering the interface and reflecting region is the forward portion of an undisplaced bi-Maxwellian distribution: *upward?*

$$f(V_{\parallel}, V_{\perp}) = n_0 \cdot \frac{(m/2k\pi)^{3/2}}{\sqrt{T_{\parallel}T_{\perp}}} \cdot \exp\left(-\frac{mV_{\parallel}^2}{2kT_{\parallel}} - \frac{mV_{\perp}^2}{2kT_{\perp}}\right), V_{\parallel} \text{ upward} \quad (17)$$

$$f(V_{\parallel}, V_{\perp}) = 0, V_{\parallel} \text{ downward}$$

If the ions enter the interface with parallel velocity $V_{\parallel 0}$, their energy is related to that inside the potential region

$$V_{\parallel 0}^2 = V_{\parallel eq}^2 + \frac{2e\Delta\Phi}{m} \quad (18)$$

where $\Delta\Phi$ is the increase in potential over that outside the interface.

Thus, the distribution function within the potential region is:

$$f(V_{\parallel}, \Delta\Phi) = n_0 \cdot \frac{(m/2k\pi)^{3/2}}{\sqrt{T_{\parallel}T_{\perp}}} \cdot \exp\left(-\frac{mV_{\parallel eq}^2 + 2e\Delta\Phi}{2kT_{\parallel}} - \frac{mV_{\perp}^2}{2kT_{\perp}}\right) \quad (19)$$

From the above equation, it can be seen that only the particles with $V_{\parallel 0}^2 \geq \frac{2e\Delta\Phi}{m}$ can reach the equator.

The fluxes at the ionosphere and the equator can be obtained by integrating the distribution functions, giving a ratio whose maximum value we may identify with our penetration ratio P :

$$P = \frac{Flux(eq)}{Flux(incoming)} = \exp\left[-\frac{e\Delta\Phi}{kT_{\parallel}}\right] \quad (20)$$

Note that $T_{\parallel}$ here is the parallel ion temperature of the the incoming flow.

3. RESULTS

In this section, we shall present trends observed in the five parameters defined in previous section. These five parameters are: (1) the maximum anisotropy (A_{max}); (2) the transition latitude (λ_{tr}); (3) the transition latitudinal scale (λ_s); (4) the anisotropy half-width (W); and (5) the penetration ratio (P) for the incoming field-aligned ions. The trends presented here are intended to provide a statistical picture of the core ion distribution in the near-equatorial inner magnetosphere. Discussion of the results in terms of simple models involving potential barriers and Liouville mapping of ion distributions along the field line is also contained in this section.

1. Occurrence trends of the ion parameters

In this section, we present the occurrence histograms for the various individual parameters. In all cases these are presented as bar graphs indicating the total number of occurrences within incremental bins spanning the range of the observed values of the particular parameter. We ~~have presented~~ the occurrence trends of the ion parameters for 43 cases.

Occurrences of Maximum Anisotropies

The dominant influence on the latitudinal ion distribution morphology is probably the maximum anisotropy (nominally the equatorial ion anisotropy). This parameter ultimately should determine, in part through Liouville mapping, the transition latitude and scale. It should also control the field-aligned flux penetration ratio through its influence on the equatorial electrostatic potential distribution. Here, we show the occurrence histogram for A_{max} in Figure 6 (first panel).

Figure 6 (top panel) indicates that the equatorial anisotropy ratio peaks broadly about $A_{max} = 4$, while 3 cases with $A_{max} \geq 10$ are observed. The average value is indicated to be $\langle A_{max} \rangle = 5.19$.

According to equation (11), for the case that $T_{\perp}$ is much smaller than the effective energy of the detector kT_d ($\approx 60\text{eV}$), we can obtain the temperature anisotropy from A_{max} :

$$T_{\perp}/T_{\parallel} \approx 2\sqrt{A_{max}} - 1 \quad (21)$$

Hence, the peak occurrence of $A_{max} = 4$ would correspond to a typical equatorial $T_{\perp}/T_{\parallel}$ of about 3. In the case of the RIMS instrument, the effects of the energy-dependent solid angle imply higher $T_{\perp}/T_{\parallel}$ than indicated by (21). For the case that $T_{\perp}/T_d \approx 1$, the average equatorial temperature anisotropy would be about 5.

~~Occurrences of~~ Penetration Ratios

One of the most interesting parameters obtained for this region is the penetration ratio P , which may be important for indicating the presence of electrostatic potential barriers and hemispheric decoupling. Figure 6 (second panel) indicates the occurrence distribution of the penetration ratios P , with P ranging from 0 to 2.

Most of the penetration ratios are less than 1, which implies the existence of positive potential layers causing reflection of the incoming ionospheric streams, and diminution of the stream inside the transition point. However, note that 10 out of 43 cases have penetration ratios greater than 1. This could indicate an accumulation of large field-aligned fluxes within an electrostatic potential well inside the transition location; such fluxes might not be instantaneously related to the incoming flux outside the transition region. The average penetration ratio for those $P \geq 1$ is 1.26 and the average value for $P \leq 1$ is 0.57.

~~Occurrences of~~ Transition Latitudinal Scales

The transition scale $\lambda_s(trapped)$ is a measure of the sharpness of the trapped ion latitudinal distribution near the transition location. Figure 6 (third panel) shows the occurrences of the transition latitudinal scales $\lambda_s(trapped)$. These display a rather strong peak in the $2 - 3^\circ$ range. As noted in the previous section, the transition scale of case 82126 10:00-12:00 was 1.29° , indicating a rather abrupt transition. However, 37 out of 42 cases (88%) have transition latitudinal scales of larger than 2 degrees, which means that most cases have more gradual transitions than the examples shown in Olsen et al. [1987].

~~among~~ Transition Latitudes

Figure 6 (bottom panel) displays the transition latitude occurrence histogram. There were 31 transitions observed in the southern hemisphere ($\lambda_{tr} \leq 0$) and 11 transitions observed in the northern hemisphere ($\lambda_{tr} \geq 0$). The average transition locations in each hemisphere were $\langle \lambda_{tr} \rangle = -5.92$ in the southern hemisphere and $\langle \lambda_{tr} \rangle = 8.30$ in the northern hemisphere. It is also seen that all trapped ion transitions occurred for $\lambda \geq -11^\circ$ and $\lambda \leq 13^\circ$, and there is a suggestion of an occurrence peak at about $\lambda = -4^\circ$.

2. Correlations ~~among~~ ^{among} the various parameters

In this section, the correlations among the five parameters and their possible interpretation will be presented. These correlations are between: (1) The anisotropy half-width (W) and the maximum anisotropy (A_{max}); (2) The transition latitudinal scale (λ_s) and the maximum anisotropy (A_{max}); (3) The transition latitude (λ_{tr}) and the maximum anisotropy (A_{max}); and (4) The penetration ratio (P) for the incoming field-aligned ions and the maximum anisotropy (A_{max}).

Correlations between Ion Anisotropy Half Width and Maximum Anisotropy

We might expect that generally the latitudinal half-width W of the trapped ion distribution should decrease as the maximum anisotropy increases: the more perpendicularly-

peaked the equatorial pitch angle distribution is, the more confined these ions are in mirroring close to the magnetic equator. Figure 7 displays W versus A_{max} for the passes considered in the survey.

In Figure 7, the data show two prominent characteristic relationships:

- (1) cases with very high A_{max} 's (larger than 7) have lower W 's (less than 4°).
- (2) cases with very high W 's (larger than 6°) have lower A_{max} 's (less than 5).

In other words, though there is considerable scatter in the data, the statistical envelope of the points is consistent with an inverse relation between W and A_{max} .

The correlation between half maximum anisotropy, W (latitudinal distance between locations with A_{max} and $\frac{1}{2}A_{max}$), and A_{max} can also be explained as follows. In the model discussed above (equation 15), we may write the ratio of the temperature anisotropy at location λ to its equatorial value as

$$\frac{T_{\perp}(\lambda)}{T_{\parallel}(\lambda)} / \frac{T_{\perp}(eq)}{T_{\parallel}(eq)} = \left\{ \left[1 - \frac{B(eq)}{B(\lambda)} \right] \frac{T_{\perp}(eq)}{T_{\parallel}(eq)} + \frac{B(eq)}{B(\lambda)} \right\}^{-1} \quad (22)$$

? looks wrong!

If we simply let the value of $A_{\lambda}/A_{max} = 1/2$ be associated with a value of $\frac{T_{\perp}(\lambda)}{T_{\parallel}(\lambda)} / \frac{T_{\perp}(eq)}{T_{\parallel}(eq)} = \gamma \leq 1$, we can rearrange this to express the value $R_{B,\gamma}$ as

$$R_{B,\gamma} = 1 - \frac{\frac{1}{\gamma} - 1}{R_{T_{eq}} - 1} \quad (23)$$

where $R_{B,\gamma}$ is the ratio of the magnetic field strength at the equator to that at the location where $A_{\lambda}/A_{max} = 1/2$. From this last equation we can see that, since $\gamma \leq 1$, as the equatorial temperature anisotropy increases, $R_{B,\gamma}$ increases, meaning that the location in λ is closer to the equator. Thus, this is consistent with our observation of smaller W 's associated with higher A 's in Figure 7. In the figure, we have tried three fitting curves: a. $T_{\perp}/T_{\parallel} = 2\sqrt{A_{max}} - 1$ (approximation for $T_{\perp} \ll T_d$), b. $T_{\perp}/T_{\parallel} = 4\sqrt{A} - 3$, (approximation

Fit?

A, Amax notational consistency?

for $T_{\perp} \approx T_d \approx 60\text{eV}$), and c. $T_{\perp}/T_{\parallel} = 3\sqrt{A}$. The fitting curves are obtained by finding the solution for the latitude where $A = A_{\frac{1}{2}\text{max}}$ in equation (23), for a given latitude of A_{max} , and hence the latitudinal distance between the locations of $A_{\frac{1}{2}\text{max}}$ and $A_{\text{max}} (W)$. As can be seen, curve b. ($T_{\perp} \approx T_d$) fits better than curve a. ($T_{\perp} \ll T_d$), which may indicate that perpendicular ion temperature is close to T_d . However, as described before, the relation between A and $T_{\perp}/T_{\parallel}$ is obtained by crude assumptions: energy dependence of the RIMS acceptance solid angle (equation 5) and $E_{\text{min}} = 0$ (assuming the spacecraft is negatively charged or unbiased to significantly simplify the approximation), which will affect the correlation between W and A_{max} . For parametric interest, we have tried curve c ($T_{\perp}/T_{\parallel} = 3\sqrt{A}$) and found it fits best to the data points.

Approximation for what?

looks like function depends on A_{max}

None fits very well!

Correlations between Ion Latitudinal Transition Scale and Maximum Anisotropy

Figure 8 shows that cases with very high A_{max} 's have smaller λ 's and cases with very large λ 's have lower A_{max} 's while a larger λ indicates a more gradual transitions. As in the relationship between A_{max} and W in Figure 7, this is because when the ion population has lower A_{max} , the equatorial pitch angle distribution is broad. Hence the ion mirror latitudes are spread over a greater latitudinal range which results in a more gradual transition. However, the data scatter is rather large in this Figure and the inverse correlation is not strong.

separate sentence

Correlations between Ion Transition Latitude and Maximum Anisotropy

Figure 9 shows the tendency that the transition latitude on either side of the equator increases with equatorial anisotropy. Note that here the transition latitude is referenced from the latitude of A_{max} which is obtained from DE orbit data. Liouville mapping of an equatorial bi-Maxwellian distribution peaked in the direction perpendicular to the magnetic field line shows that the distribution becomes increasingly isotropic moving away from

the equator. This approach toward isotropy is slower with latitude for lower equatorial anisotropy. The correlation between W and A_{max} as shown above shows that the decrease of anisotropy with increasing latitude is faster for higher A_{max} cases. On the other hand, the larger the anisotropy at the equator, the further it has to decrease overall to attain a ^{value} ~~an~~ anisotropy of 1.2. This latter effect is ~~the~~ ^{dominant}, and the latitude of transition (to $A < 1.2$) ~~is~~ ^{is} larger for larger anisotropy ~~cases~~, as is clearly seen in Figure 9.

We can also interpret this feature by Liouville mapping. According to our definition, the transition latitude is the location where ~~the count rate ratio of pitch angle $\alpha = 90^\circ$ and $\alpha = 45^\circ$ equals 1.2.~~ $A = 1.2$. Assume the perpendicular temperature is much smaller than the detector temperature, we get $T_{\perp\lambda}/T_{\parallel\lambda} = 2\sqrt{A} - 1$ and hence $T_{\perp\lambda}/T_{\parallel\lambda} \approx 1.2$. Equation (22) could be written in the following form:

$$R_{B,tr} = \frac{1}{6} + \frac{1}{6[R_{T_{eq}} - 1]} = \frac{1}{6} \frac{R_{T_{eq}}}{R_{T_{eq}} - 1} \quad (24)$$

where $R_{B,tr}$ is the ratio of the magnetic field strength at the equator to that at the transition point. It can be seen that $R_{B,tr}$ decreases as $R_{T_{eq}}$ increases, i.e. λ_{tr} increases as $R_{T_{eq}}$ increases. That is, as the equatorial temperature anisotropy increases, the transition latitude will be farther away from the equator.

Again, according to equation (22), we can find fitting curves for the correlation between λ_{tr} and A_{max} by assuming different relations between $T_{\perp}/T_{\parallel}$ and A_{max} . We have tried two different cases, $T_{\perp}/T_{\parallel} = 3.2\sqrt{A}$ and $T_{\perp}/T_{\parallel} = 3.3\sqrt{A}$ (the curves vary with the coefficient between $T_{\perp}/T_{\parallel}$ and $\sqrt{A}$ sensitively.), and found both two curves show the increases of λ_{tr} as A_{max} increases. The curve with $T_{\perp}/T_{\parallel} = 3.2\sqrt{A}$ fits better in the northern hemisphere, and that with $T_{\perp}/T_{\parallel} = 3.3\sqrt{A}$ fits better in the southern hemisphere.

Correlations between Ion Penetration Ratio and Maximum Anisotropy

what relation
to eq 11 &
Associated approxi-
mations?

Guess transition ~~don't~~ to $A > 1.2$ dominated
many times by elec & statics, not
magnetic minor gas medly.

In Figure 10, we plot the penetration ratios versus equatorial anisotropy parameter (A_{max}). The top panel shows the original points, while the bottom panel shows averages within bins of 1 unit of A_{max} . As can be seen, there is a clear trend for the penetration ratios to decrease with higher equatorial trapped ion anisotropy. This can be readily understood by noting that higher equatorial ion temperature anisotropies will generally lead to greater positive potential values, tending to reflect a larger fraction of the incoming field-aligned stream back toward the ionosphere, and reduce its penetration into the equatorially-trapped ion region.

It is difficult to find a straightforward correlation between A_{max} and P by utilizing Liouville mapping because a variety of factors are involved. For simplicity, we assume all the transition points are located at $\lambda = 6^\circ$ such that $R_B=1.06$ and further assume the parallel ion temperature of cold ionospheric flow to be 0.5eV. For parametric interest, in Figure 11, we fix electron temperature at $T_e=10\text{eV}$ such that $kT_e T_{\parallel i} / e [T_e + T_{\parallel i}]$ varies from 0.1 to 5, corresponding to $T_i=0.1$ to 10 eV. It can be seen, from all the curves, that penetration decreases as A_{max} increases and all the data points distribute in the range of the curves associated with $T_i=0.1$ eV and $T_i=10$ eV.

From the correlations between A_{max} versus $\Delta\Phi$ and $\Delta\Phi$ versus P , the trend between A_{max} and P may be ~~as~~ interpreted as depicted schematically in Figure 12. If we assume for the sake of argument that (1) the equatorial electron distributions are approximately isotropic or at least uncorrelated with the ion anisotropy, (2) that the actual equatorial ion perpendicular temperature is not negatively correlated with the anisotropy, and (3) that the effects of the higher energy ring current particles will not change the trend, then the higher the anisotropy, the greater the equatorial positive potential peak. The larger the positive potential peak, the greater the repulsion and flux reduction of incoming field-aligned ion streams. This keeps these field-aligned ions from reaching the equator, and results in the decrease of the penetration ratio.

see
 comments
 29.16

NOT for $P > 1$!

4. DISCUSSION AND CONCLUSION

This report concerns an investigation of core plasma evolution on outer plasmasphere flux tubes by data analysis techniques, which we believe has revealed several interesting characteristics of the plasma behavior in this inner magnetosphere region.

In the analysis of DE-1/RIMS core ion data, we have characterized the interface between trapped and field-aligned ion distribution regions observed during the unique "field-line skimming" orbits of the Dynamics Explorer-1 spacecraft. In this analysis, we have characterized such features as the equatorial ion flux anisotropy, the penetration of field-aligned ionospheric streams into the equatorial region, the scale of the transition into trapped ion populations, and the transition latitude. We find that there is a trend for the penetration ratio, the anisotropy half width, and the transition scale length to decrease with a higher equatorial ion anisotropy.

Liouville mapping of equatorially trapped ions and the reflection of the incoming ionospheric ion streams from the equatorial potential peaks associated with such trapped ions have been utilized to interpret these features. Olsen et al. [1994] used the same mapping equations to show observation data points for fitted $T_{\perp}$ at various latitudes about the equator along an $L=4.6$ field line for pass on January 5, 1984. This distribution of $T_{\perp}$ agrees very well with equation (15) if $T_{\perp eq}/T_{\parallel eq} = 40$, and the density agrees with estimated values when $T_{\perp eq}/T_{\parallel eq} = 18$. The agreement of the observed density and temperature distribution with the calculated values suggests the distribution of such differential- anisotropy produced electrostatic potentials, is likely to be as calculated, with a peak near the equator and the decrease toward the ionosphere of 1-2 volts. One of the most important effects such potentials will have on the core plasma evolution is the reflection of incoming field-aligned ionospheric streams keeping them from penetrating the equatorial region. This has been reported by Olsen et al [1987]. The present report provides a statistical survey

Anisotropy
1/2 width
Anisotropy
scale
length

relating several of the aspects dealt with in the case studies of Olsen et al. [1987,1993].

One of the major contributions in this report has been ~~through data analysis approach~~ to reveal the effects of the equatorial ion temperature anisotropy on the latitudinal profiles of plasma parameters along the field line. Similar to simulation results of Lin et al. [1994], this study shows results indicating the existence of a positive potential barrier around the equator and reflection of field-aligned ion streams. From the interpretation of our observational results, we find that as the equatorial ion temperature anisotropy increases, the equatorial potential increases and hence penetration of field-aligned ion streams decreases.

We may compare the potential drops obtained from simulations with those obtained for the same equatorial parameters in the Liouville mapping from equation (16). To compare with the simulation results in Lin et al. [1994] (Figure 1a.) we first assume that the equatorial parameters are $T_e \approx 0.6$, $T_{i\parallel} = 1.1$, and $R_{T_{eq}} = 16$. In the simulations, we note that the potential drops from the equator to $\lambda = 10^\circ$ and $\lambda = 20^\circ$ are 0.5 and 1 V, respectively. Substituting the above equatorial parameters into equation, we would obtain potential drops $\Delta\Phi = 0.43$ at $\lambda = 10^\circ$ and $\Delta\Phi = 0.76$ at $\lambda = 20^\circ$. These two sets of values are remarkably close. One reason that the potential drops in the simulation are larger is that there is an electron temperature gradient which makes an additional contribution to the potential drop.

To make an estimate ~~for~~ of the potential drop for a given equatorial ion temperature anisotropy observed in the data, we take case 82-126 as an example. According to Olsen et al. [1987] the perpendicular ion temperature and A_{max} for case 82-126 are about 8 eV, so that the equatorial ion temperature anisotropy $R_{T_{eq}}$ can be estimated to be ≈ 5 from equation 12 (for the case $T_\perp \approx T_d \ll 60$ eV and $A_{max}=10$). Hence, the parallel ion temperature is about 1.6 eV. If we consider cases of $T_e = 0.1, 1$, and 10 eV, the estimated potential drops at the transition latitude ($\lambda=6.7^\circ$) would be 0.02, 0.13 and 0.30 Volts.

~~$T_\perp \ll T_d \approx 60^\circ$~~ $T_d \equiv 60 \text{ eV!}$

For these different estimates, with penetration ratio $P=0.3$, the thermal energies for the incoming streams would be 0.017, 0.11 or 0.25 eV (according to equation (20)), respectively. The latter estimate is reasonably close to the thermal energies for the ionospheric polar wind source. It may also be noted that the streaming ions themselves may alter the potential drop from that obtained by simple mapping of the equatorial plasmas alone, possibly sharpening the drop and allowing a greater fraction of the total drop between the equator and the ionosphere to occur across this transition latitude.

Here, we summarize the statistical trends in five parameters for 43 latitudinal transition events. Indicated trends at this stage include the following:

1. Transition ~~latitudes~~ occur at latitudes below 13° , and about 30% of these occur very close to the equator at $\lambda \leq 5^\circ$.
2. A broad range of equatorial ion anisotropies are seen, but the typical values would be consistent with bi-Maxwellian temperature ratios of $T_\perp/T_\parallel$ of about 3.
3. The latitudinal scales for the edges of the trapped ion populations display a rather strong peak in the $2 - 3^\circ$ range.
5. Most cases have penetration ratio $P < 1$, which implies the ion reflection due to positive electrostatic potential layers. $P > 1$ might indicate an enhancement of the near-equatorial flux possibly due to trapping of field-aligned ions in a potential well around the equator. These trapped field-aligned ions may not directly be related to the field-aligned ions outside the transition latitude.
6. A higher equatorial A_{max} causes a ^{smaller} ~~lower~~ anisotropy half width and a smaller transition scale length and higher transition latitude.
7. There is a clear trend for the penetration ratios to decrease with higher equatorial trapped ion anisotropy. This may be interpreted as follows: larger equatorial temperature anisotropies are associated with larger positive electric potential peaks, leading to greater repulsion and flux reduction of incoming field-aligned ion streams, hence a decrease of the

penetration ratio.

ACKNOWLEDGMENT

This research was supported by NASA grants NAG8-134 and NAGW-2128 to the University of Alabama in Huntsville. We would like to thank B. L. Giles, R. C. Olsen and D. R. West for providing help in utilizing the facilities and data bases at Marshall Space Flight Center for this study. We would also like to acknowledge valuable discussions with S. Boardsen and M. Thomsen.

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Figure 1: Spin-time spectrogram of low-energy H^+ fluxes for a DE-1 pass on May,6, 1982 (82-126: Year 82-, Day 126). This case illustrates a rather abrupt transition between trapped and field-aligned ion regions and a low penetration ratio of field-aligned flows into the equatorial region.

Figure 2: Spin-time spectrogram of low-energy H^+ fluxes for a DE-1 pass on March 9, 1984 (Year 84- Day 068). This case illustrates a more gradual transition and higher penetration ratio than case 82-126.

Figure 3: DE-1 orbit for day 126 of 1982. This orbit shows a rather small L-shell variation between $\lambda = -10^\circ$ to $\lambda = 0^\circ$ ($\Delta L = 0.13$)

Figure 4: DE-1 orbit for day 295 of 1983. This orbit shows a rather large L-shell variation between $\lambda = 10^\circ$ to $\lambda = 0^\circ$ ($\Delta L = 0.36$).

Figure 5: Countrates, their ratios and illustration of parameter definitions for the pass on day 126 of 1982. (a) shows the time of the pass on maximum flux anisotropy (A_{max}) and nominal equator(from DE-OA data), (b) shows the penetration ratio of field- aligned flows (P), and (c) shows the transition time and transition scale length which indicates the sharpness of the transition.

Figure 6: Occurrence trends of the ion parameters.

Figure 7: Correlations between Ion Anisotropy Half Width (W) and the Maximum Anisotropy (A_{max}). The three fitting curves are obtained from equation (23), assuming three relations between ion flux anisotropy (A) and ion temperature anisotropy.

Figure 8: Correlations between ion transition scale (λ_s) and maximum anisotropy (A_{max}). Generally, λ_s tends to decrease as A_{max} increases, indicating a more abrupt transition for a higher A_{max} .

Figure 9: Correlations between Ion Transition Latitude (λ_{tr}) and Maximum Anisotropy (A_{max}). The two fitting curves are obtained from equation (22).

Figure 10: Correlations between Ion Penetration Ratio (P) and Maximum Anisotropy A_{max} . It can be seen that P tends to decrease as A_{max} increase.

Figure 11: Fitting curves between P and A_{max} for different parallel temperatures of the equatorial ions. Theses curves are obtained by setting transition latitude $\lambda_{tr} = 6^\circ$ and $T_e = 10$ eV.

Figure 12: Schematic representation of increased equatorial trapped ion anisotropy resulting in high potential barriers and decreased field-aligned ion stream penetration.

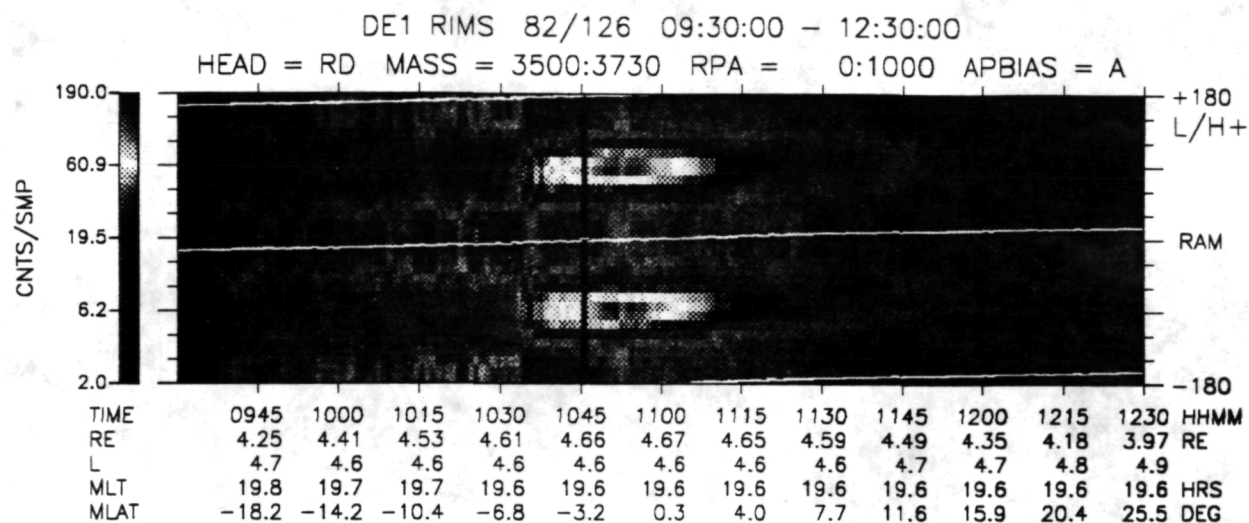


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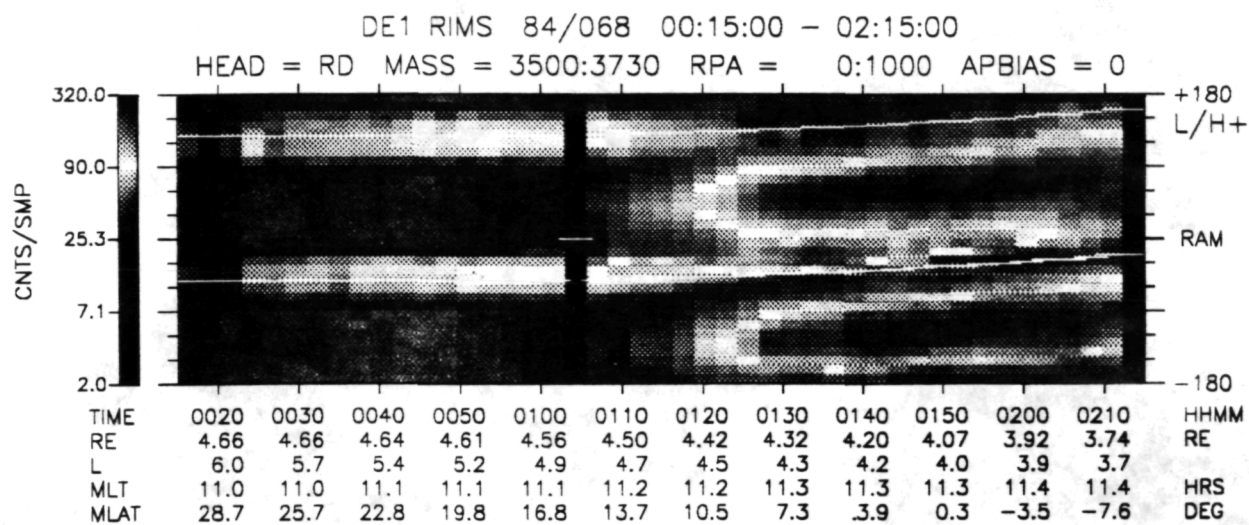


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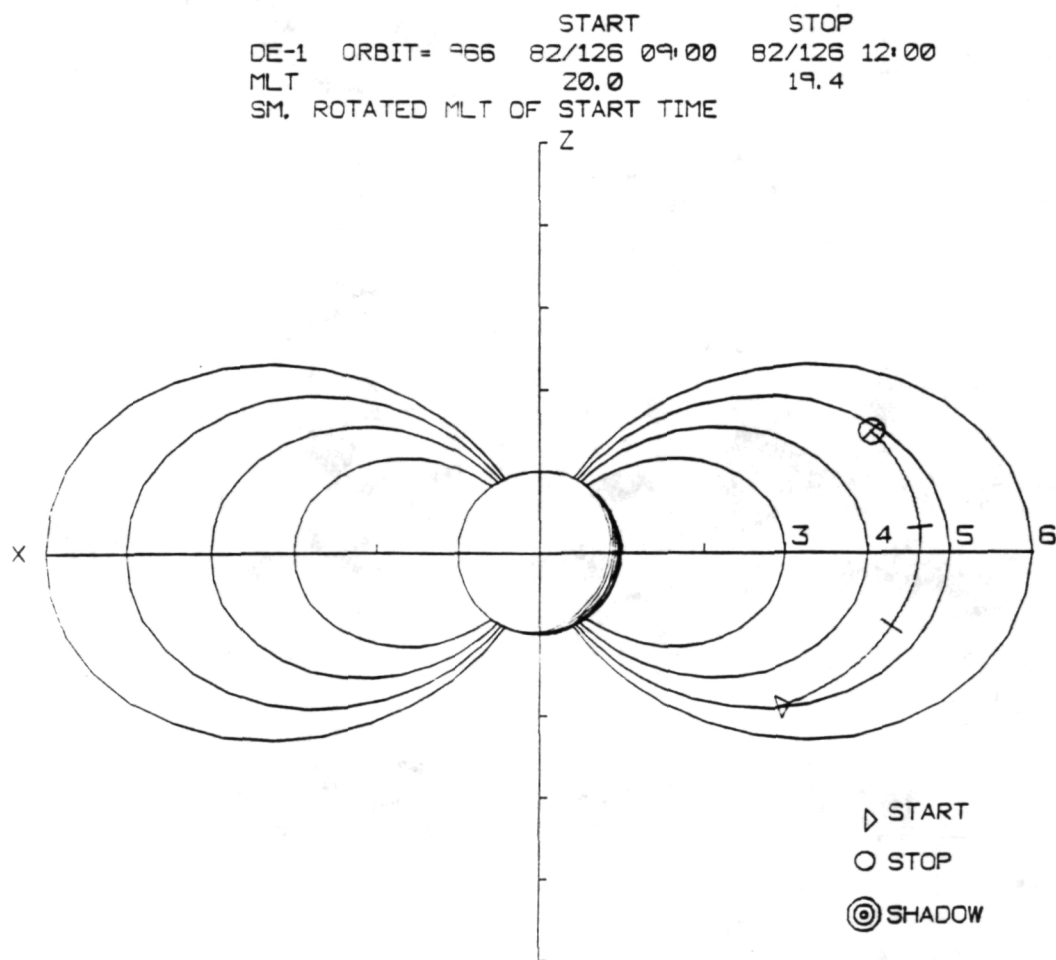


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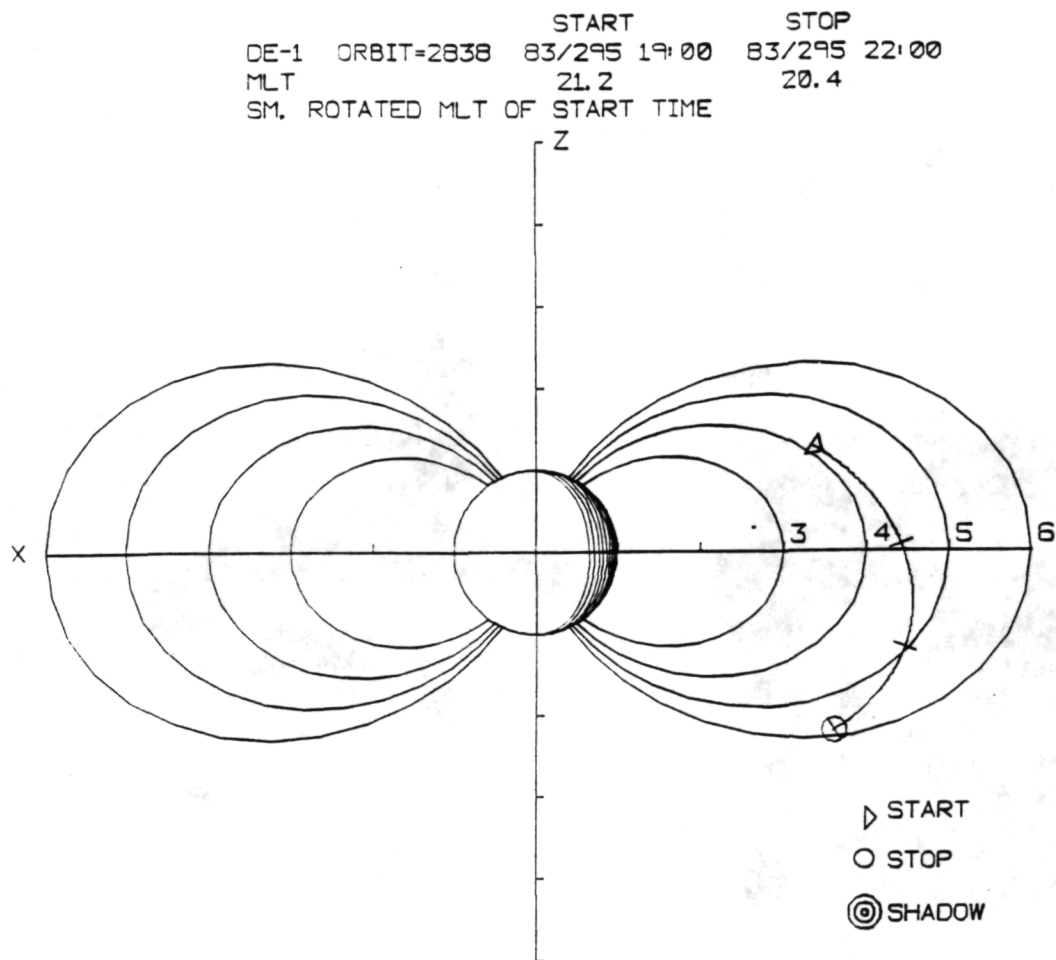


Figure 4: DE-1 orbit for day 295 of 1983. This orbit shows a rather large L-shell variation between $\lambda = 10^\circ$ to $\lambda = 0^\circ$ ($\Delta L = 0.36$).

DE RIMS C-T SUMMARY (V3.4) 82/126 6-MAY 10.00.00-12.00.00
 Trapped (ram angle = 70 TO 110) FA (ram angle = -20 TO 20)

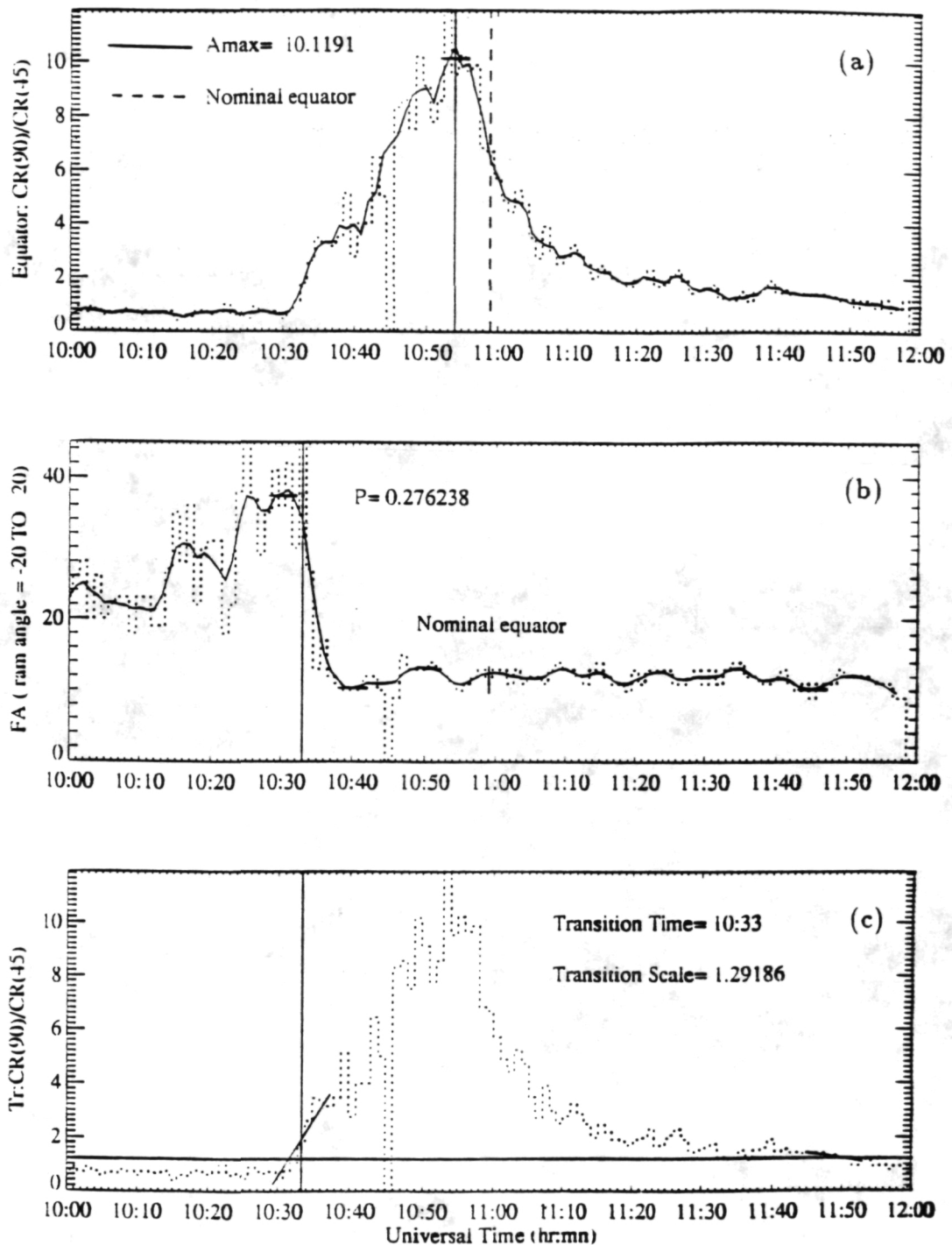


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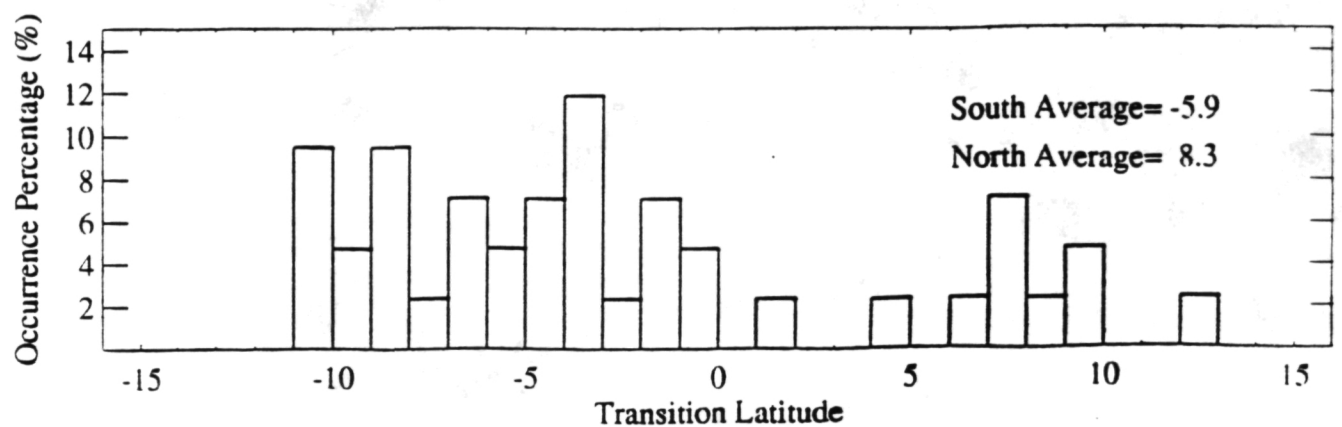
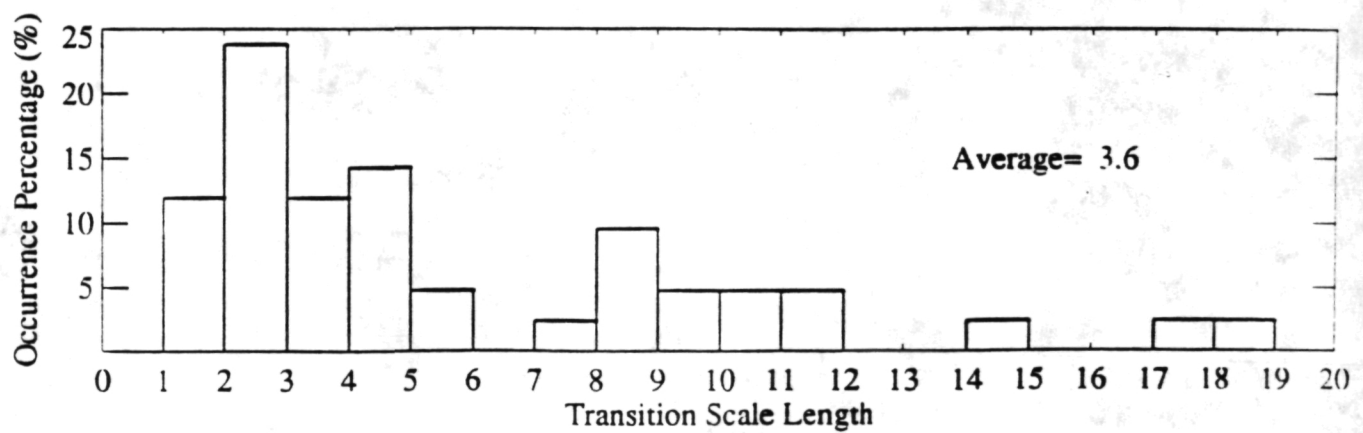
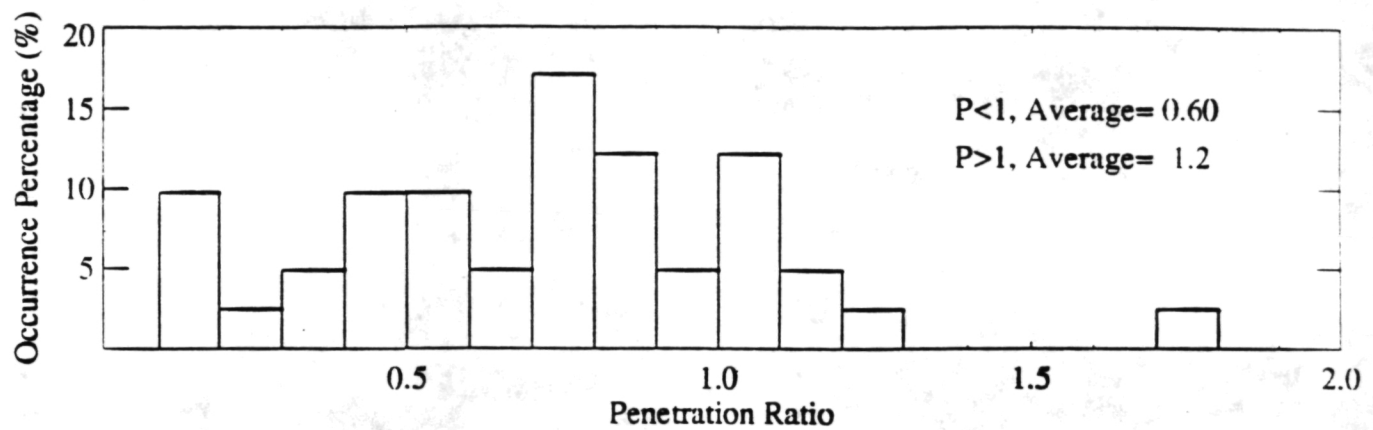
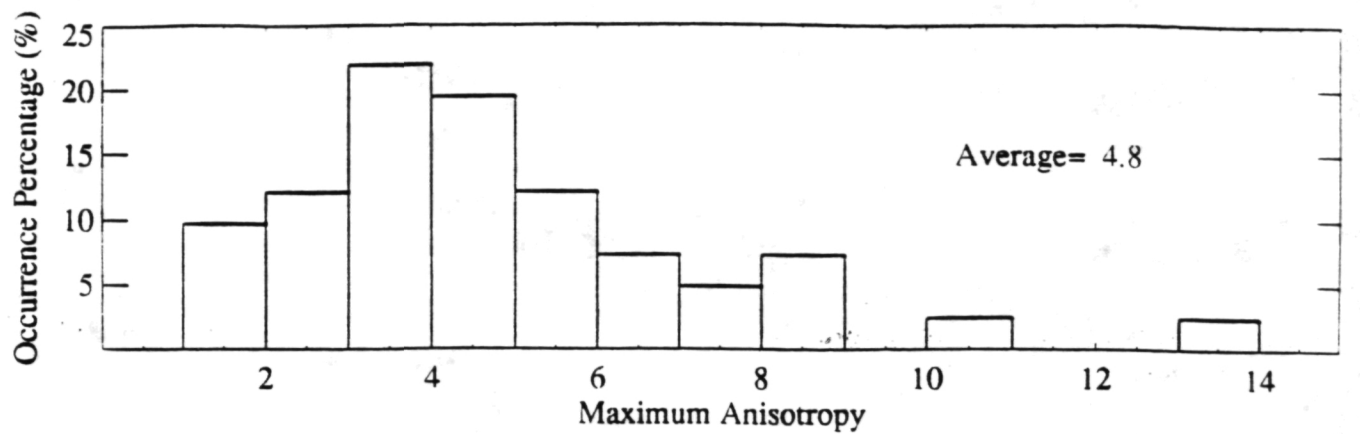


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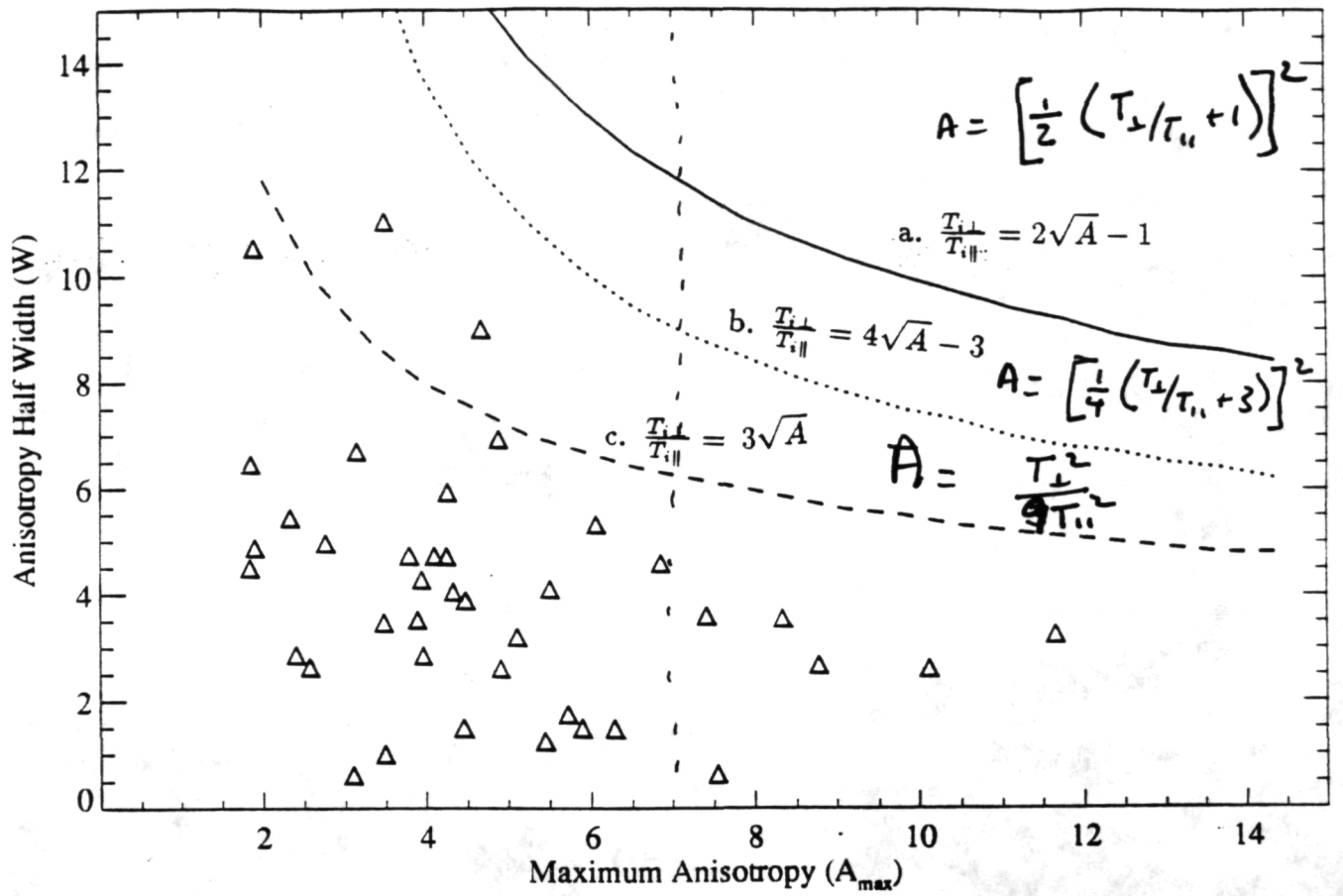


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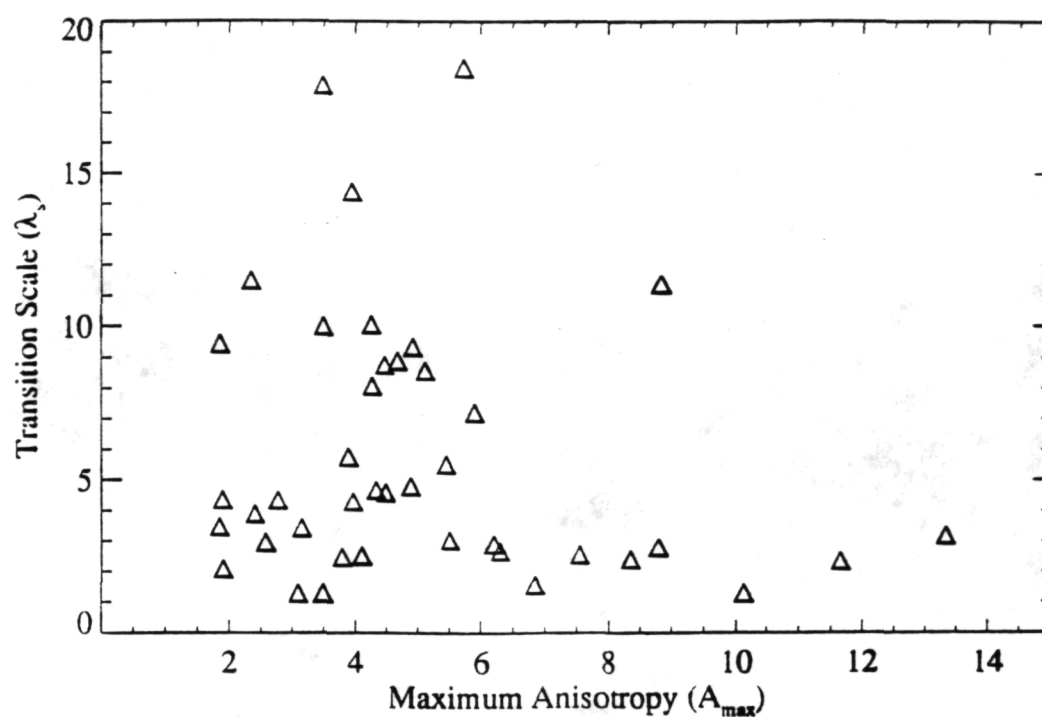


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3.2 and 3.3

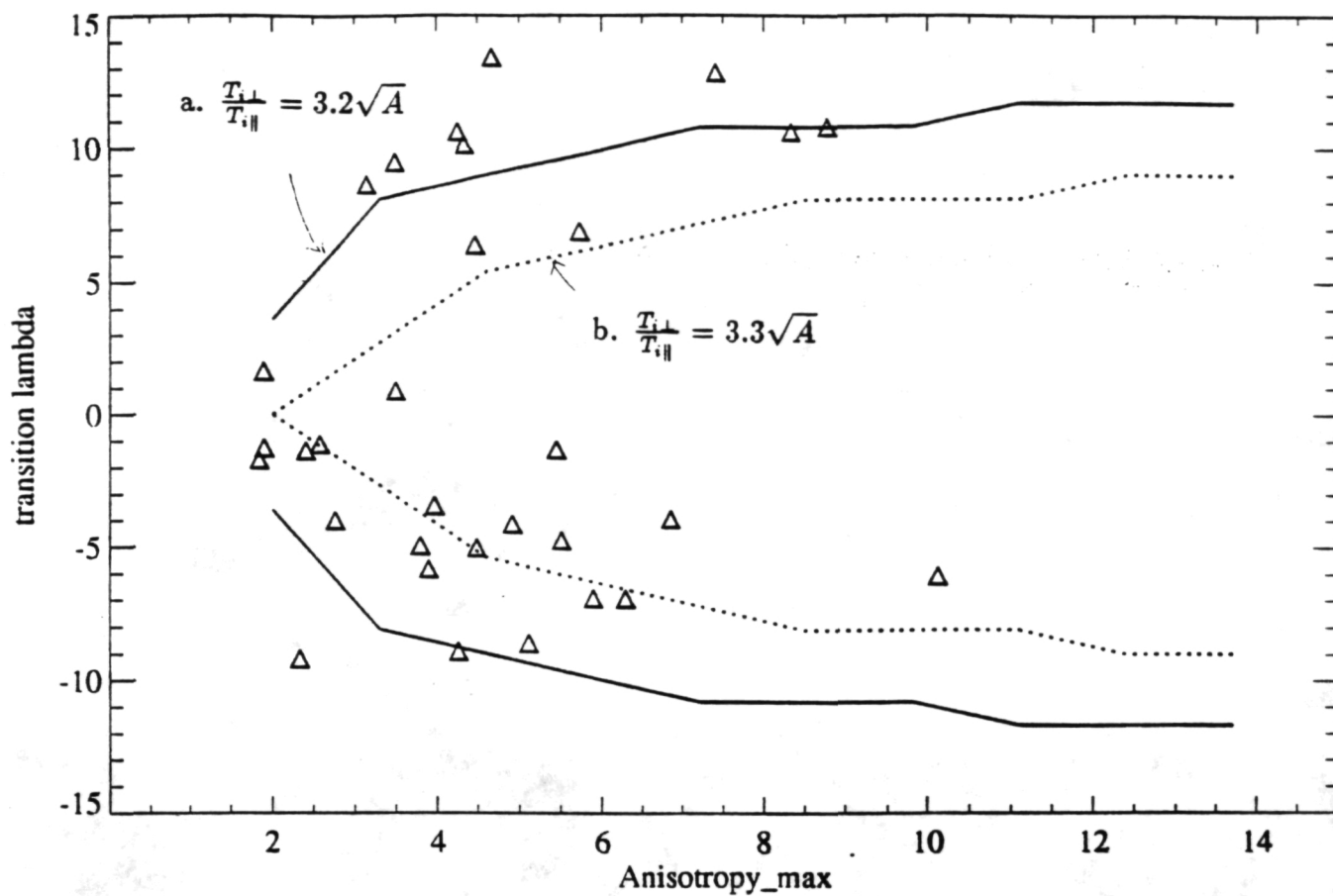


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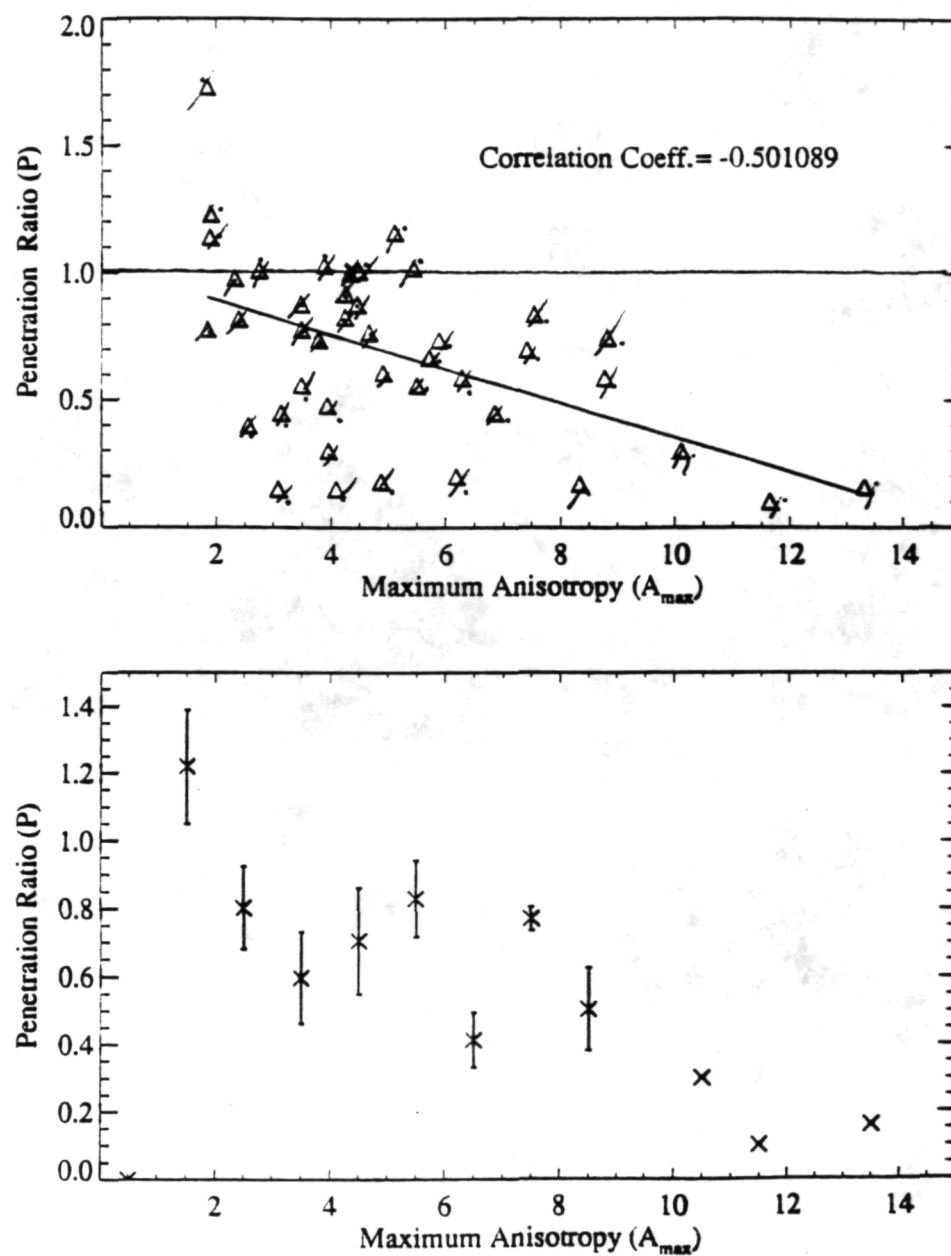


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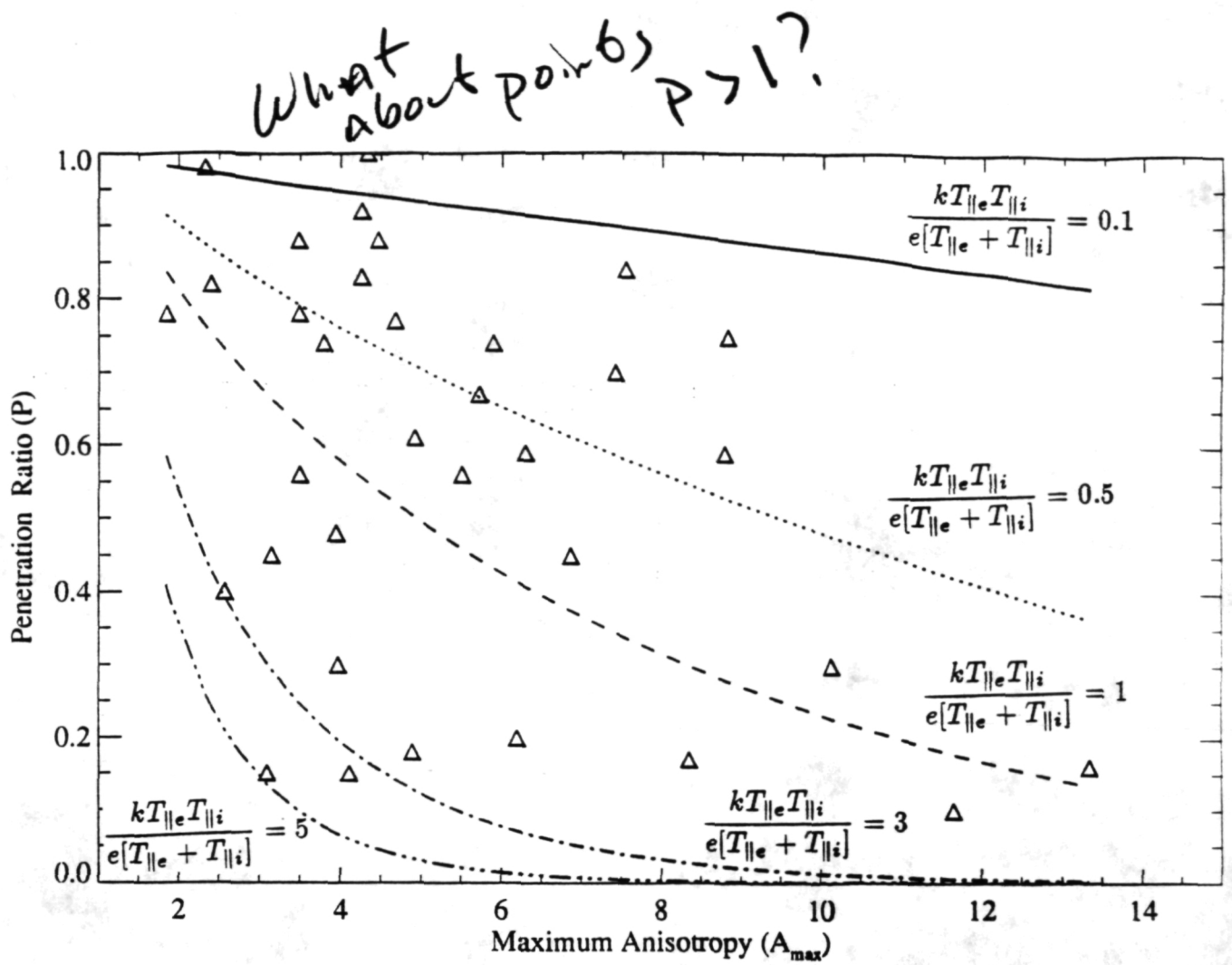


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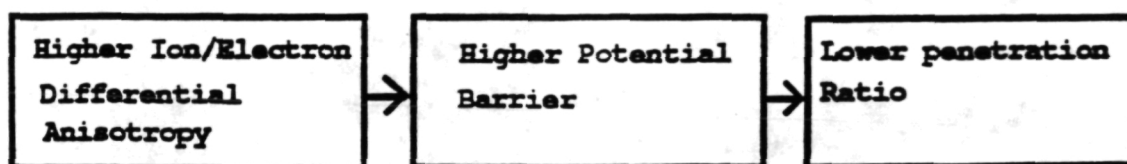
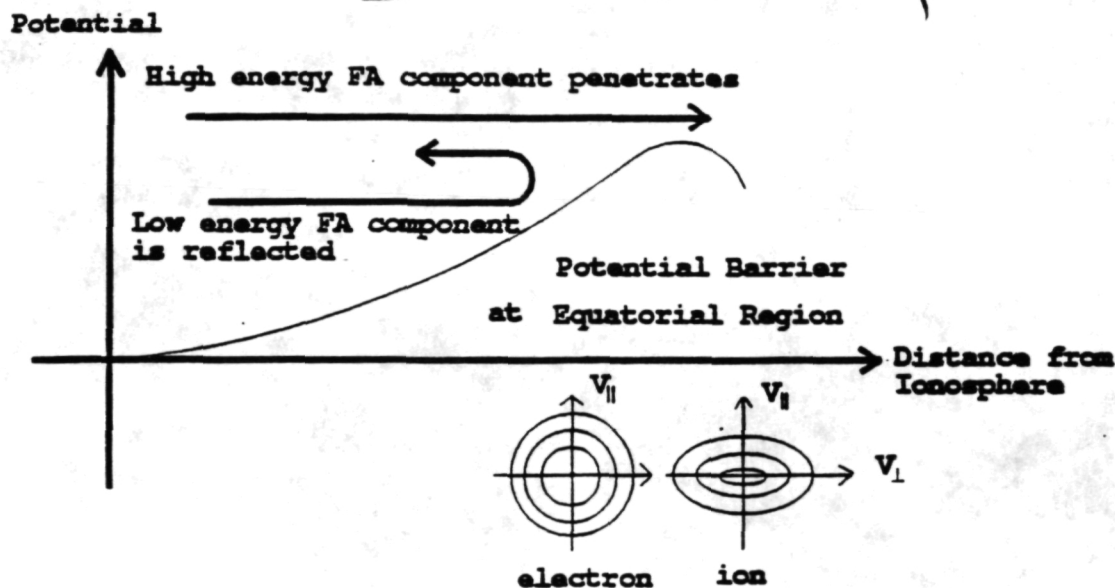


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